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First-line Filter Debris Analysis Study

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Contract Number: W7707-007849/001/HAL

Contract Scientific Authority: Gary Fisher, (902) 42 7-0550 ext. 3432

Defence R&D Canada

Contractor Report
DREA CR 2001-182
July 2002

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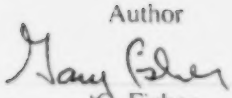

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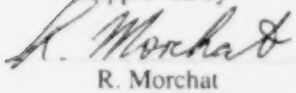

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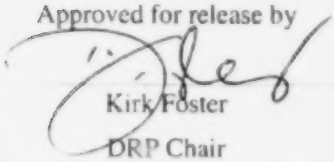

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Abstract

For the past two decades filter debris analysis (FDA) has been used as a diagnostic technique to ascertain information about the wear state of CH124 main gearboxes (MGB) and turbine engines.

Two FDA technologies, which optimize sample preparation and eliminate analyst variability were evaluated for first-line filter debris analysis capability for the CH124 Sea King helicopter.

1. FilterCHECK, which backwashes the filter, running the fluid through a sensor which simultaneously counts and sizes metallic wear particles.
2. Intelligent Debris Analyzer (IDA), which optically counts, sizes, and determines the morphology of metallic wear particles.

The Intelligent Debris Analyzer (IDA) was an accurate FDA analysis tool but was found to be sensitive to the operator and its environment. Therefore, the IDA is an unlikely candidate for first-line FDA.

The FilterCHECK was observed to be an accurate filter debris extraction and analysis tool for use by first-line maintenance technicians. Therefore, FilterCHECK should be field trialed to further assess its design, operation and operator training requirements.

Résumé

Au cours des deux dernières décennies, l'analyse des débris de filtre a été utilisée comme technique de diagnostic pour vérifier des renseignements au sujet de l'usure des boîtes de transmission principale (BTP) et des moteurs à turbine des CH124.

Deux techniques d'analyse des débris de filtre, lesquelles maximisent la préparation de l'échantillon et éliminent le problème de variation des analystes, ont fait l'objet d'une évaluation de la capacité d'analyse des débris de filtre au premier échelon pour les hélicoptères Sea King.

1. Le FilterCHECK effectue le lavage du filtre en faisant passer le liquide dans une sonde, laquelle compte et détermine simultanément la dimension des particules d'usure métalliques.
2. L'analyseur de débris intelligent effectue optiquement le comptage, le dimensionnement et il détermine la forme des particules d'usure métalliques.

L'analyseur de débris intelligent s'est avéré être un outil précis d'analyse des débris de filtre. Il est toutefois sensible à l'utilisateur et aux conditions environnementales. Par conséquent, il est peu probable que l'analyseur de débris intelligent soit utilisé pour l'analyse des débris de filtre au premier échelon.

On a constaté que le FilterCHECK était un outil précis d'analyse et d'extraction de débris pouvant être utilisé par les techniciens de maintenance au premier échelon. Le FilterCHECK devrait faire l'objet d'un essai sur le terrain pour permettre d'en analyser davantage la conception, et l'utilisation et de déterminer les besoins en formation pour les utilisateurs.

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Executive Summary

Introduction: Filter debris analysis (FDA) is a diagnostic technique used to ascertain information about the wear state of mechanical system components by examining particulate trapped on scavenge lube oil filters. Manual FDA, involving a trained analyst, has been utilized in a laboratory as a condition-monitoring tool for CH124 main gearboxes (MGB) and turbine engines for approximately two decades.

There are two impediments to current FDA techniques that render it impractical for first line application.

1. Time-consuming membrane patch preparation for microscopic evaluation.
2. Technician efficacy varies drastically for the tedious task of counting and sizing of metallic wear particles.

Two FDA technologies, which have minimized the above impediments, were evaluated for first-line filter debris analysis capability for the Sea King helicopter.

1. FilterCHECK, which backwashes the filter, running the fluid through a sensor that simultaneously counts and sizes metallic wear particles.
2. Intelligent Debris Analyzer (IDA), which optically counts, sizes, and determines the morphology of metallic wear particles.

Principle Results: FilterCHECK is an accurate filter debris extraction and analysis tool for use by first-line maintenance technicians. When coupled with Lube Analyst condition monitoring software, FilterCHECK provides a quick and accurate assessment of equipment health.

IDA is also an accurate FDA tool, equal to FilterCHECK in its assessment capabilities. However, it is sensitive to the operator and environmental conditions. Therefore, IDA is an unlikely candidate for first-line FDA.

Significance of Results: The applicable FilterCHECK statistical condition indicator guidelines for the various wear regimes, based on all FilterCHECK data, should be applied to the T58 Engine and the CH124 Main Gearbox (MGB).

FilterCHECK should be field trialed to assess its design, operation and operator training requirements.

Further work on some of IDA's technical issues, particularly sample placement, particle morphology identification and result reporting could enhance its capabilities as a 2nd line condition monitoring tool.

Holmes, M. & Donahue, A. 2001. First-line Filter Debris Analysis Study. DREA CR 2001-182 Defence Research Establishment Atlantic.

Sommaire

Introduction : L'analyse des débris de filtre est une technique de diagnostic utilisée pour vérifier des renseignements au sujet de l'usure des composants de systèmes mécaniques grâce à l'examen des particules retenues dans les filtres d'huile de récupération. Les analyses manuelles, lesquelles mettaient à contribution un analyste compétent, ont été utilisées en laboratoire comme outil de contrôle d'état des boîtes de transmission principale (BTP) et des moteurs à turbine des CH124 depuis environ deux décennies.

Deux inconvénients des techniques actuelles d'analyse des débris de filtre font en sorte que celles-ci ne peuvent être utilisées au premier échelon.

1. Longue période de préparation de l'échantillon sur membrane en vue de l'évaluation au microscope.
2. Variation importante de l'efficacité des techniciens en ce qui a trait aux tâches fastidieuses de comptage et de dimensionnement des particules d'usure métalliques.

Deux techniques d'analyse des débris de filtre, lesquelles ont atténué les inconvénients mentionnés plus haut, ont fait l'objet d'une évaluation de la capacité d'analyse des débris de filtre au premier échelon pour les hélicoptères Sea King.

1. Le FilterCHECK effectue le lavage du filtre en faisant passer le liquide dans une sonde, laquelle compte et détermine simultanément la dimension des particules d'usure métalliques.
2. L'analyseur de débris intelligent effectue optiquement le comptage, le dimensionnement et il détermine la forme des particules d'usure métalliques.

Résultats principaux : Le FilterCHECK est un outil précis d'analyse et d'extraction de débris pouvant être utilisé par les techniciens de maintenance au premier échelon. Lorsqu'on le combine au logiciel Lube Analyst, le FilterCHECK fournit une évaluation rapide et précise de l'état de l'équipement.

L'analyseur de débris intelligent est aussi un outil précis d'analyse des débris de filtre dont les capacités d'évaluation sont équivalentes au FilterCHECK. Cependant, l'analyseur est sensible à l'utilisateur et aux conditions environnementales. Par conséquent, il est peu probable que l'analyseur de débris intelligent soit utilisé pour l'analyse des débris de filtre au premier échelon.

Importance des résultats : Les lignes directrices pertinentes de l'indicateur de données statistiques d'état du FilterCHECK pour les divers régimes d'usure, d'après l'ensemble des données du FilterCHECK, devraient être appliquées au moteur T58 et à la boîte de transmission principale (BTP) du CH124.

Un essai sur le terrain du FilterCHECK devrait permettre d'en analyser la conception, et l'utilisation et de déterminer les besoins en formation pour les utilisateurs.

Des travaux plus approfondis concernant certaines questions techniques relatives à l'analyseur de débris intelligent, en particulier la mise en place de l'échantillon, la détermination de la forme des particules et les rapports sur les résultats, pourraient améliorer ses capacités comme outil de contrôle d'état au deuxième échelon.

Holmes, M & Donahue, A. 2001. *First-line Filter Debris Analysis Study.* CRDA DCD 2001-182 Centre de recherches pour la défense Atlantique.

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1. Introduction/Background

Filter debris analysis (FDA) is a technique whereby diagnostic information about the wear state of mechanical system components is obtained by examining particulate trapped on scavenge lube oil filters. FDA has been utilized as a condition-monitoring tool for CH124 main gearboxes (MGB) and turbine engines for approximately two decades. Traditionally this usage has been as a second-line condition monitoring technique in a laboratory environment. FDA has primarily been used when other first-line condition monitoring techniques (SOA, chip lights, etc.) have indicated potential problems. The advent of fine lube oil filtration has rendered the results of some first-line condition monitoring techniques, such as spectrometric oil analysis (SOA) and ferrography, suspect. More emphasis is now being placed on FDA as an Integrated Health Monitoring (IHM) technique but current manual FDA methods are not conducive for first-line use.

There are two impediments to use of FDA as a first-line technique. First, current FDA practice requires the preparation of membrane patches to permit microscopic evaluation. Preparation of these patches is time-consuming, often requiring a full day for a full set of MGB filters. Second, examination of the FDA patch requires counting and sizing of metallic wear particles. This procedure is tedious and its efficacy can vary drastically from one analyst to another. Utilization of FDA as a first-line condition monitoring technique will require shortening of the process and less reliance on highly trained and experienced technicians.

This project evaluates two technologies that could enable the use of FDA as a first-line condition monitoring technique. One of the technologies is the FilterCHECK, which backwashes the filter, running the fluid through a sensor which simultaneously counts and sizes metallic wear particles. The other technology is the Intelligent Debris Analyzer (IDA), which optically counts, sizes, and attempts to determine the morphology of metallic wear particles. The aim is to evaluate these technologies for suitability as a first-line, deployable filter debris analysis capability for the Sea King helicopter.

GasTOPS, at Reference [1], was tasked to complete the work outlined in References [2] and [3]. A brief outline of the tasks is as follows:

- Arrange for installation and training of 12 AMS IHM shop personnel on the IDA (from Tektrend International, Montreal) and the FilterCHECK 100 (from GasTOPS Ltd., Ottawa);
- Set up systems to record relevant operational parameters of the filters (TSO, filter hours etc), relevant IHM information such as chip lights or other IHM techniques (vibration analysis, ferrography), and the actual data from the FilterCHECK and IDA;
- Obtain used CH124 MGB lube oil filters (No.1 Lube, No.2 Lube, Torquemeter Pump filters) and used T58-GE-8F/100 engine lube oil filters for use with the FilterCHECK 100 and IDA;

- Prepare a report assessing the capabilities of FilterCHECK and IDA as first-line FDA devices. Provide recommendations on improvements to equipment and/or processes to better enable use of FDA as a first-line technique.

- This final report builds upon the data and observations made since delivery of the interim study at Reference [4].

2. References

1. PWGSC Contract W7707-007849/001/HAL, 29 May 2000.

2. Annex A Statement of Work, Filter Debris Comparative Study.

3. GasTOPS Ltd. Proposal P-6-149, Rev 3, Proposal for Filter Debris Analysis Comparative Study, 16 May 2000.

4. GasTOPS Ltd. Report, GTL-6-149-TR.1, First-line Filter Debris Analysis Study Interim Report, November 2000.

5. Toms, A., Machinery Oil Analysis, 2nd Edition, 1998, Coastal Skills & Training

6. Riech, J.G., C Curve Fitting and Modeling for Scientist and Engineering, McGraw-Hill Inc.

3. Observations

3.1 FilterCHECK Cleaning Process

FilterCheck automates the filter cleaning process necessary for FDA. Debris is removed from lube oil filters by pressurized pulses of solvent. The debris/solvent slurry thus generated is then passed through a device that counts ferrous (FE) and non-ferrous (NFE) particles in several different size ranges. The FilterCHECK wash cycle lasts 15 minutes compared to the several hours required for performing the manual FDA technique. Pending future analysis, the FilterCHECK cycle time could be reduced by more than 60% as the majority of the particles are cleaned from the filter in the first 5 to 7 minutes of the 15 minute wash cycle.

The Sea King MGB has three different lube oil filters (No.1 Lube Pump, No.2 Lube Pump, and Torquemeter Pump) sharing a common lubricating oil system. There are also two different types of gearboxes. The 21000 series MGB uses 46-micron reusable metal disk type filters that are cleaned using an air pressure of 55 psi. The 21000 series MGB torquemeter pump lube filter has a stack of filter disks approximately 1/3 the height of the No.1 and No.2 lube pump filters. The initial FilterCHECK air pressure setting of 55 psi was causing damage to the filter disks. An air pressure of 40 psi was therefore used for the torquemeter pump lube filters and 55 psi for all other filters. These pressures were found to be most effective in removing the debris from these types of filters.

The 24000 series MGB uses 10 micron paper disposable filters that are also cleaned at 55 psi. These filters have a "Dirt Alert" strip, that is an oil resistant, fibrous material interwoven around the circumferential surface area of the pleated filter. The "Dirt Alert" strip interferes with the debris removal process of 24000 series MGBs filters by trapping the particles in the fibre and, due to the loose attachment to the filter significantly reduces the effectiveness of the FilterCHECK washing cycle. Where the "Dirt Alert" strip had been removed prior to installation, FilterCHECK removes debris from the 24000 series MGB filters as efficiently as the 21000 series metal disk type filters. Alternate, and less costly, 24000 series MGB filter part numbers, without the "Dirt Alert" strip, have been provided to the Technical Authority for use. Publication Discrepancy Reports have been raised to standardise filter usage.

The T58 turbine engine lube filter also consists of a stack of metallic filter disks. There have been no issues with the cleaning process of these filters. They are also cleaned at a pressure of 55 psi.

To assess the debris removal capabilities of the FilterCHECK, 17 MGB filter sets were cleaned using FilterCHECK and then membrane patches were prepared from the debris in the capture basket. These same filters were then cleaned using the normal ultrasonic cleaning method and more membrane patches prepared. Five of these patches were routed to DREA who confirmed their cleanliness. Debris from the remaining twelve filters patches were then washed into a solvent and the solvent run through the FilterCHECK. The retained metallic debris counted after a single FilterCHECK run was typically less than 10% of the total metallic debris counted. Refer to Figure 3-1 for a comparison of metallic debris counts after a

single FilterCHECK run and the metallic debris counts from the same filters cleaned ultrasonically.

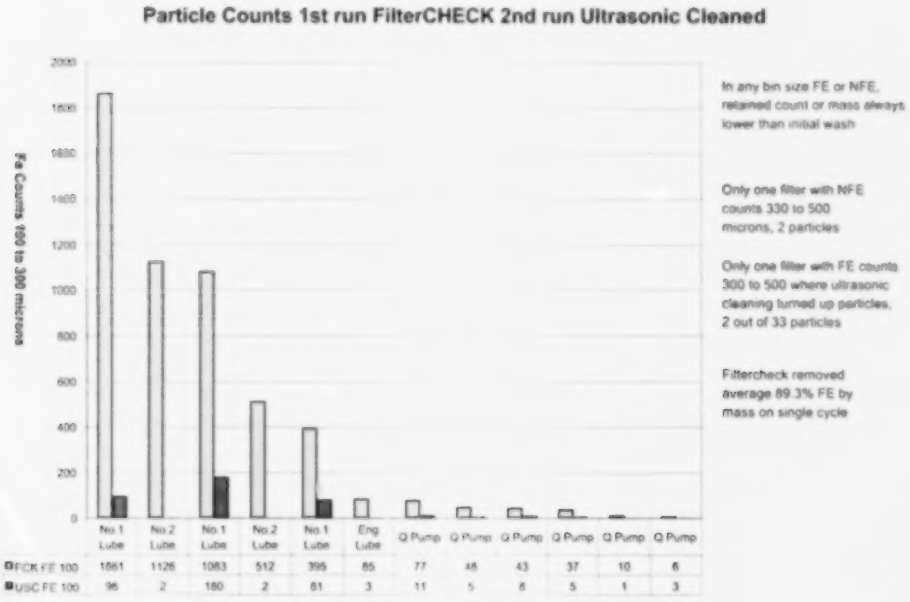

Figure 3-1 FilterCHECK 1st Pass vs. Ultrasonic 2nd Pass Debris Removal

In fourteen sets of the three filters, FilterCHECK has determined that, on average, and regardless of filter hours, the No.1 Lube Pump filter accounts for 73% of the total metallic particles counted, that the No.2 Lube Pump filter accounts for 24% and the Torquemeter Pump filter accounts for 3%. Refer to Figure 3-2 for a comparison chart of the particle counts obtained by filter type.

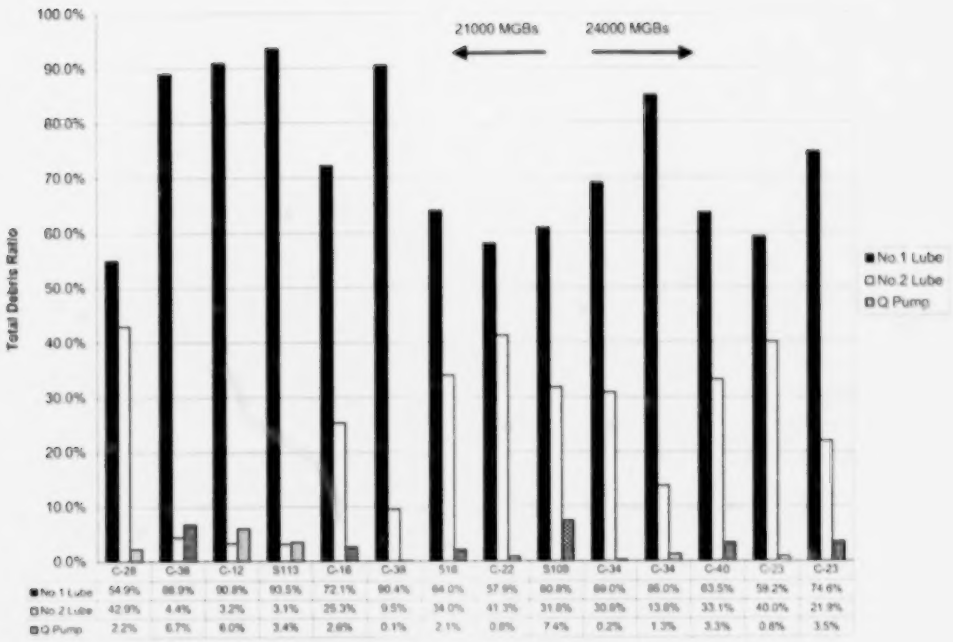

Figure 3-2 Sea King MGB Debris Removal by Filter Type

3.2 FilterCHECK Wear Rate Determination

FilterCHECK extracts the debris and provides ferrous (FE) and non-ferrous (NFE) metallic debris counts in four bin sizes as follows:

	Ferrous	Non-Ferrous
Bin 1	100 to 300 microns	330 to 500 microns
Bin 2	300 to 500 microns	500 to 750 microns
Bin 3	500 to 915 microns	750 to 1000 microns
Bin 4	915 microns & larger	1000 microns and larger

The majority of components (mechanical, static, dynamic, electrical) have a probability of failure over the life of the component similar to the "Bathtub Curve" in Figure 3-3. In a physical sense, the probability of failure for a new or overhauled component, recently installed into a system, is initially high during some break-in period. This probability lowers after the initial break-in period, but will eventually increase again as the component approaches wear-out failure.

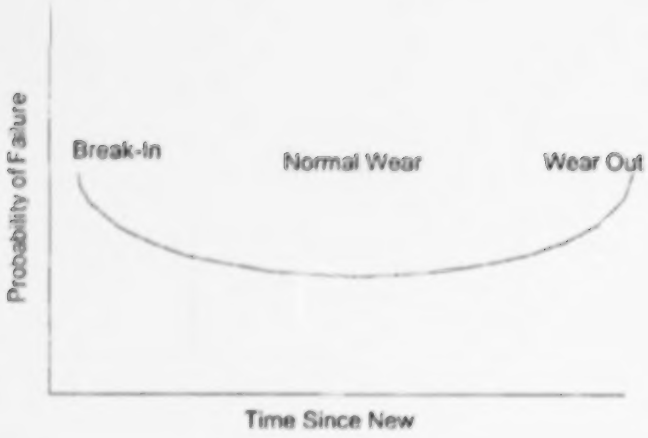

Figure 3-3 Classic Bathtub Curve

Statistical condition indicator guidelines (Figures 3-4, 3-5 & 3-6), under development for the Sea King MGB, indicate that the particle count per filter hour rate follows a similar trend to the "Bathtub Curve". The Figures all exhibit a normal "break-in" wear region, where the particle production rate is initially high due to the rubbing of rotating parts. This rate then tapers off to a quasi-stable or "normal" wear region. Finally, in the "wear-out" region, the particle production rate exponentially increases until the components begin generating unacceptable amounts of wear debris. Maximization of useful life of the MGB depends on understanding when the MGB has entered this "wear-out" region, allowing for a scheduled overhaul and/or other applicable maintenance tasks.

A set of status indicators has been associated with the particle wear rate limits (statistical condition indicator guidelines) for FilterCHECK. These status indicators are words (Normal, Monitor and Investigate) that are selected to convey specific maintenance instructions to first-line condition monitoring technicians. "Normal" means that the wear rate is within expected values. "Monitor" means that the wear rate is marginally outside expected values and that an accelerated monitoring schedule is necessary to further assess component condition. Finally, "Investigate" indicates that the component is operating outside expected values, and requires maintenance action to confirm condition. Maintenance action could mean any measure from in-depth manual FDA to system removal.

There is significant statistical uncertainty in the "Break-In" and "Wear-Out" wear regimes for the MGB statistical condition indictor guidelines (see Tables E-1 through E-9). Therefore, only the "Normal" wear regime Monitor and Investigate indicators, shown in Tables 3-1 and 3-2, respectively, should be implemented. The indicators are expressed in terms of particle counts per filter hour with the exception of FE Mass, which is expressed in terms of milligrams per filter hour.

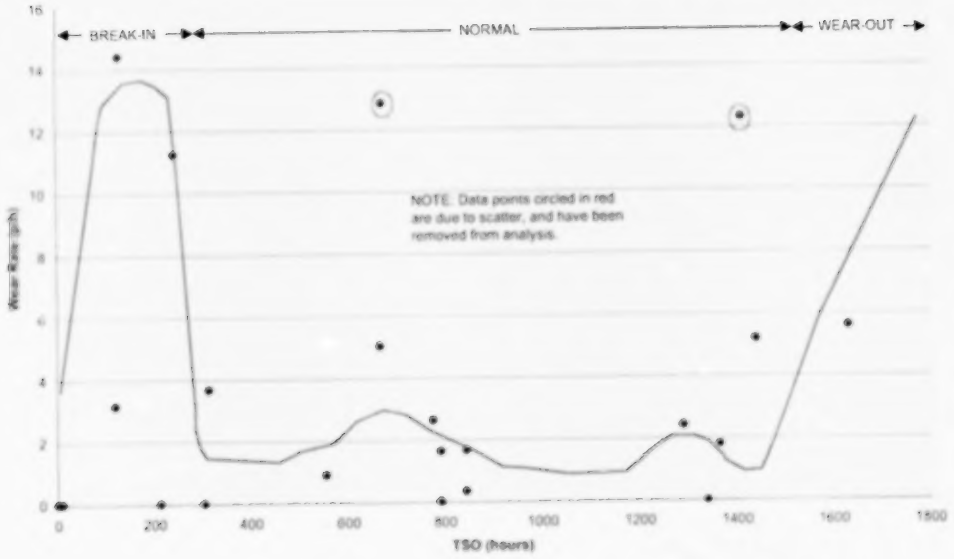

Figure 3-4 FE 100 – Lube #1 Filter Wear Rate versus Time-Since-Overhaul (TSO)

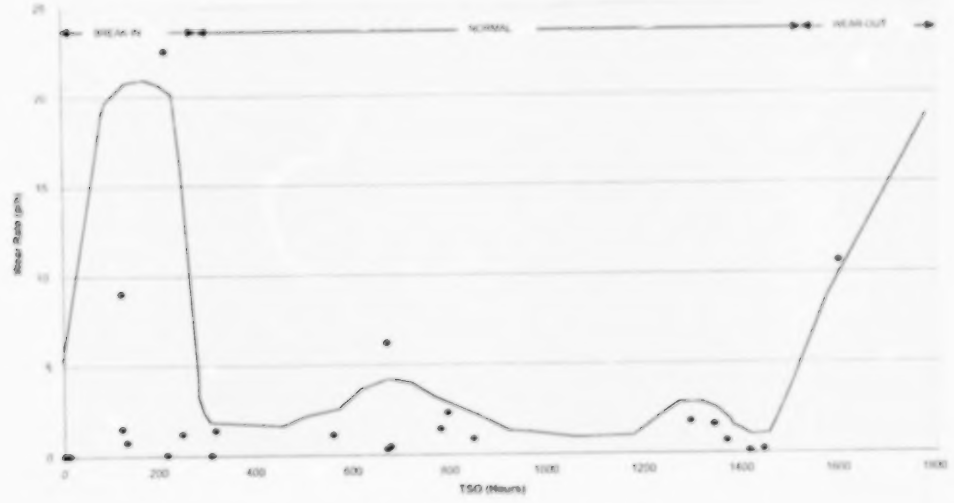

Figure 3-5 FE 100 – Lube #2 Filter Wear Rate versus TSO

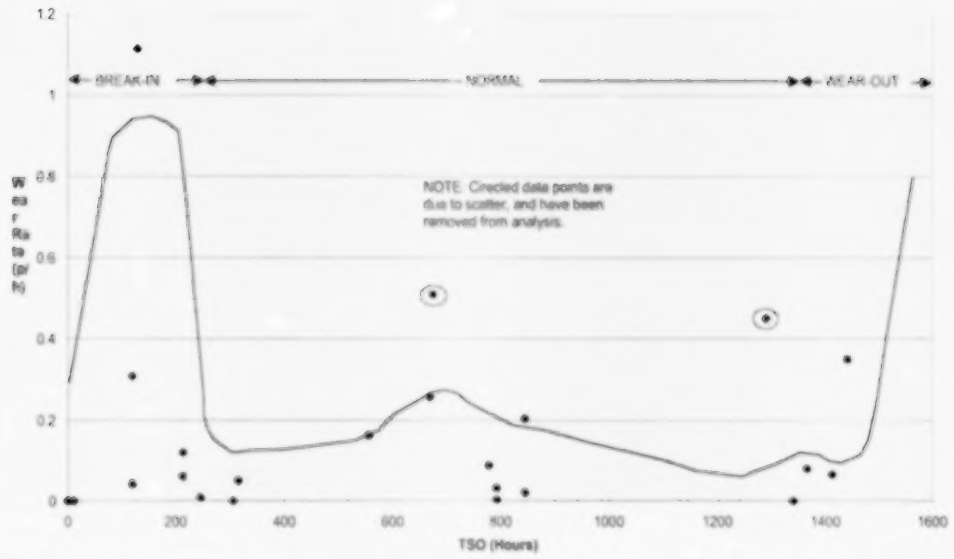

Figure 3-6 FE 100 – Torquemeter Pump Filter Wear Rate versus TSO

Pending further analysis, development of condition indicators based on examination of a single filter instead of all three may be feasible. Currently, however, condition indicators are being developed for each filter.

There is currently no significant difference for the values of the T58 Engine wear-rate condition indictor guidelines with-respect to the various wear regimes (See Figure 3-7). As more data becomes available, the wear regimes of the T58 Engine may become more pronounced, requiring statistical condition indictor guidelines for each wear regime. Presently, all data has been analyzed to provide statistical condition indicator guidelines (see Tables 3-3 & Table E-10) for the T58 turbine engine, irrespective of the wear regime.

The data in the largest ferrous and non-ferrous bin sizes is consistently nil, and has been dropped as a potential condition indicator parameter (see Appendices A, B and E).

TABLE 3-1 FILTERCHECK STATISTICAL CONDITION INDICATOR (MONITOR[1]) GUIDELINES FOR THE CH124 MGB

	Break-in Wear			*Normal Wear*			*Wear-Out*		
	#1 Lube	***#2 Lube***	***Q Pump***	***#1 Lube***	***#2 Lube***	***Q Pump***	***#1 Lube***	***#2 Lube***	***Q Pump***
FE Mass	1.154032	0.448132	0.065227	0.199186	0.093357	0.022702	0.627202	0.011377	0.023262
FE Counts	22.24045	10.17767	1.166952	5.17591	2.474021	0.527487	16.12512	0.2654	0.622448
NFE Counts	0.011438	0.01821	0	0	0.104167	0.002347	0	0	0
FE Bin 1	21.21996	9.860875	1.124685	5.059194	2.43855	0.515069	15.70298	0.287753	0.609699
FE Bin 2	0.985631	0.281787	0.036374	0.130183	0.051597	0.012269	0.507225	0.046802	0.012749
FE Bin 3	0.171564	0.03642	0.015114	0.004756	0.007525	0.003303	0.034686	0	0
FE Bin 4	0	0	0	0	0	0	0	0	0
NFE Bin 1	0	0.01821	0	0	0.097222	0.002347	0	0	0
NFE Bin 2	0	0	0	0	0.006944	0	0	0	0
NFE Bin 3	0.011438	0	0	0	0	0	0	0	0
NFE Bin 4	0	0	0	0	0	0	0	0	0

TABLE 3-2 FILTERCHECK STATISTICAL CONDITION INDICATOR (INVESTIGATE[2]) GUIDELINES FOR THE CH124 MGB

	Break-in Wear			*Normal Wear*			*Wear-out*		
	#1 Lube	***#2 Lube***	***Q Pump***	***#1 Lube***	***#2 Lube***	***Q Pump***	***#1 Lube***	***#2 Lube***	***Q Pump***
FE Mass	1.849293	0.789756	0.114642	0.319909	0.141252	0.038028	0.940844	0.015107	0.038642
FE Counts	34.49114	17.79279	2.04456	8.29349	3.782032	0.88178	24.34682	0.377181	1.03414
NFE Counts	0.020313	0.033092	0	0	0.193452	0.004386	0	0	0
FE Bin1	32.8303	17.22404	1.973925	8.103173	3.73445	0.861497	23.70443	0.434111	1.011973
FE Bin2	1.629551	0.505384	0.061411	0.218373	0.081516	0.02059	0.820332	0.08138	0.022167
FE Bin3	0.304697	0.066185	0.027666	0.008391	0.013367	0.006	0.061602	0	0
FE Bin4	0	0	0	0	0	0	0	0	0
NFE Bin 1	0	0.033092	0	0	0.180556	0.004386	0	0	0
NFE Bin 2	0	0	0	0	0.012897	0	0	0	0
NFE Bin 3	0.020313	0	0	0	0	0	0	0	0
NFE Bin 4	0	0	0	0	0	0	0	0	0

[1] Statistical Condition Indicator Monitor Guidelines are calculated from data in Appendix A as average plus 2 times the standard deviation [4]. See Tables E-1, -2, -3, -4, -5, -6, -7, -8 & -9.
[2] Statistical Condition Indicator Investigate Guidelines are calculated from data in Appendix A as average plus 4 times the standard deviation [4]]. See Tables E-1, -2, -3, -4, -5, -6, -7, -8 & -9.

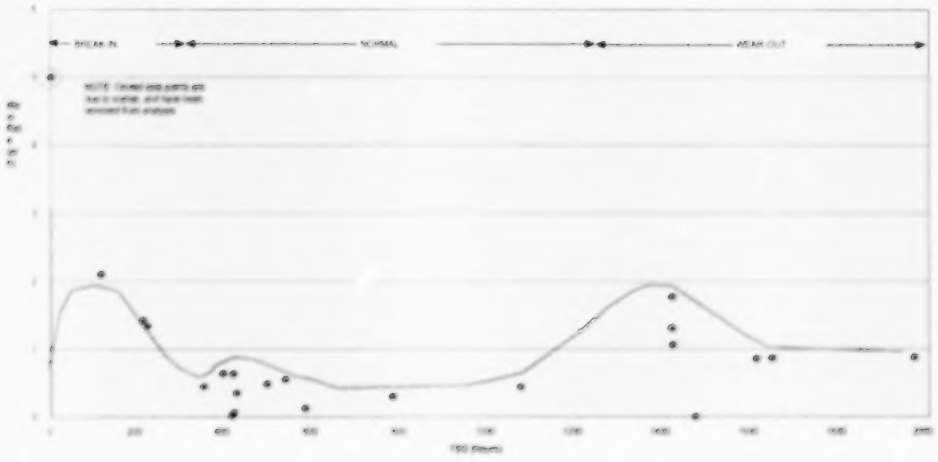

Figure 3-7 FE 100 – T58 Engine Lube Filter Wear Rate versus TSO

TABLE 3-3 FILTERCHECK STATISTICAL CONDITION INDICATOR GUIDELINES FOR THE CH124 T58 ENGINE

	Monitor[3]	*Investigate*[4]
	#1 Lube	***#1 Lube***
FE Mass	0.2259377	0.3905049
FE Counts	3.594317	6.0696999
NFE Counts	0.0055572	0.0103939
FE Bin1	3.1855154	5.3367885
FE Bin2	0.4288237	0.7774395
FE Bin3	0.0195403	0.0347967
FE Bin4	0	0
NFE Bin 1	0.0055572	0.0103939
NFE Bin 2	0	0
NFE Bin 3	0	0
NFE Bin 4	0	0

[3] Statistical Condition Indicator Monitor Guidelines are calculated from data in Appendix A as average plus 2 times the standard deviation [5]. See Table E-10.
[4] Statistical Condition Indicator Monitor Guidelines are calculated from data in Appendix A as average plus 4 times the standard deviation [5]. See Table E-10.

3.3 Intelligent Debris Analyzer (IDA)

IDA performs an automated optical scan of a filter debris patch and has the ability to count and size wear particles as well as identify particle morphology. This feature uses optical recognition of a prepared sample patch for debris particles. The ferrous patches require 20 to 25 minutes for analysis and the non-ferrous patches up to an hour. This is an improvement over the manual analysis method, which can take up to two hours a patch.

Patches were prepared for IDA analysis from the debris collected by FilterCHECK cleaning of filters. Currently, the patch is placed on the microscope stand, which is set at approximately the 50th gradation on the x and y axis, and the patch is positioned by ensuring the internal light touches the relative back left corner of the patch. This method of patch placement and alignment has identified the following features of IDA that require improvement:

- A method of ensuring that the patch/slide is placed in the same position each time would greatly enhance sample repeatability. The current method of aligning the microscope light to the back of the patch creates variability in IDA results.

- The stepwise movement of the control servos that move the platform, on which the patch/slide rests, are sufficiently abrupt (jerky) to cause the slide to move relative to the platform. A method of securing the slide to the platform should be implemented in parallel with repeatable positioning.

- The stitch size should be reviewed, as a large percentage of the patch is not scanned with the current 9x12 frame. A 13x17 frame seems more appropriate for the patches used at the 12 AMS IHM Shop.

- The fibre optic lights should be permanently mounted and position fixed to remove variability in shadows around the particles. This ultimately affects repeatability of particle size recognition as the light intensity changes each time the technician attempts to optimize the position of the fibre optic lights. Note that implementation of positioning and securing of the patch/slide are logical precursors to this suggestion.

- A process for regularly checking the white balance of the camera is required. There is difficulty in obtaining a consistent colour pallet from the camera. This ultimately affects repeatability of wear type pattern recognition as the colour pallet varies from sample to sample.

Investigation into trending and graphing of the first sample for a component is required. Initially, when a new component is entered into the IDA database, there is no data upon which the IDA can trend and compare to allow application of its expert system. In other words, going from zero particles in 300 hours (an unpopulated database) to 1 particle in 300 hours creates a sharp increase in the trend level of the component, resulting in the IDA condition indicator software providing a wear state assessment of "Investigate" where this may in fact be "Normal" wear production. Initially the software returned "Unavailable" in this situation, as expected, indicating there was insufficient data for IDA to apply its expert system.

3.4 Comparisons FilterCHECK/IDA

FilterCHECK cleans filters automatically whereas IDA still requires patch preparation. Once FilterCHECK has removed the debris from the filter, IDA requires on average 1.5 hours to separate and prepare the ferrous/non-ferrous patches, scan the patches by microscope, segment particles, and print a report. FilterCHECK requires on average 23 minutes to produce a report, saving almost an hour and a quarter of time over the IDA process.

IDA provides wear particle morphology recognition (see Appendix C & D) whereas FilterCHECK does not. IDA recognizes from 28% to 43% of the morphology of the total particles on any given patch. Particle recognition decreases with increased debris on the patch. This recognition rate can lead to misunderstandings. Condition monitoring technicians often have an analytical ferrographic background, and low particle morphology recognition rate may lead to a false conclusion.

IDA particle counting and sizing features differ from counts and sizes obtained with FilterCHECK 25-30% of the time. This is most likely due to effects of the debris pattern on a patch as compared to FilterCHECK, which counts particles streaming in oil through the sensor.

Prior to this project, the 12 AMS IHM shop had been working with DREA to develop a first-line filter debris capability. To accomplish this, ferrous (FE) and non-ferrous (NFE) debris were manually separated, sized and counted in four discrete size ranges by a technician using a microscope. These values were entered into Lube Analyst and limits were established by comparing the size and quantity values to the qualitative analysis carried out by DREA. Values were adjusted until they reflected a similar condition assessment as provided by DREA. The FilterCHECK was then set with similar size bins and the same alarm levels applied to determine equipment condition. These limits are detailed in Table 3-4.

TABLE 3-4 FILTERCHECK ORIGINAL CONDITION INDICATOR GUIDELINES FOR THE CH124 MGB & T58 ENGINE

	MGB (All Filters)			T58		
	Normal	Monitor	Investigate	Normal	Monitor	Investigate
FE Mass	0.00	0.83	1.67	0.00	1.25	2.50
FE Counts	0.00	2.70	10.70	0.00	2.05	7.80
NFE Counts	0.00	0.27	1.07	0.00	0.20	0.78
FE Bin 1	0.00	2.00	8.00	0.00	0.75	3.00
FE Bin 2	0.00	0.50	2.00	0.00	0.60	2.30
FE Bin 3	0.00	0.10	0.50	0.00	0.50	2.00
FE Bin 4	0.00	0.10	0.53	0.00	0.20	0.50
NFE Bin 1	0.00	0.20	0.80	0.00	0.08	0.30
NFE Bin 2	0.00	0.05	0.20	0.00	0.06	0.23
NFE Bin 3	0.00	0.01	0.05	0.00	0.05	0.20
NFE Bin 4	0.00	0.01	0.02	0.00	0.02	0.05

DREA had also provided input into the limits used by IDA in assessing wear states. IDA classifies debris into bin ranges (microns) similar to that of FilterCHECK. Unfortunately, MGB results of the IDA classifications (particle rates for different bin ranges) differ by a factor of 2 to 3 with FilterCHECK results; making it difficult to use IDA to confirm FilterCHECK results and vice versa. Similarly, T58 turbine engine results of the IDA classifications differ by as much as a factor of 2 with FilterCHECK results (see Appendix A & B).

Table 3-5A details IDA, FilterCHECK and manual FDA results for all completed samples. The following points can be inferred from this Table:

- IDA, DREA and FilterCHECK expert system recommendations differ on average 55% of the time for FDA performed on MGB Filters. (Note and compare all IDA. and FilterCHECK Wear Assessment Comparison in Table 3-5B.)

- IDA and FilterCHECK expert system recommendations differ 22% of the time for FDA performed on MGB Filters after 1-November-2000, and only 4% on average. (Note and compare all IDA. and FilterCHECK Wear Assessment Comparison in Table 3-5C.)

- The IDA and FilterCHECK expert system recommendations differ on average 67% of the time for FDA performed on Engine Filters. (Note and compare all IDA. and FilterCHECK Wear Assessment Comparison in Table 3-5C.)

    - Tables 3-5B, 3-5C and 3-5D were compiled from the data in Table 3-5A. Also, it was determined that FilterCHECK results prior to 1-November-2000 were based on total particle production regardless of operational hours on the filter. After 1-November-2000 FilterCHECK results were based on the particle rate of production, accounting for operational differences in individual filters

In the preliminary review of statistical condition indicator guidelines, it is evident that current FilterCHECK and IDA limits are artificially conservative (slightly low). Statistically for FilterCHECK, statistical condition indicator guidelines (Tables 3-1, 3-2 and 3-3) exceed current guidelines (Table 3-4) by a factor of 2 to 11. Therefore, the statistical condition indicator guidelines in Tables 3-1, 3-2 and 3-3 should be implemented to reduce the number of artificial Lube Analyst expert system alarms due to the current artificially low guidelines (Table 3-4).

Both IDA and FilterCHECK provide wear state conclusions and have reporting features. Although there are aesthetic differences between the IDA and Lube Analyst reports, there are two differences among the major required features (needed for filing, identification and condition assessment/analysis by an Integrated Health Monitoring laboratory) compared in Table 3-6. Since IDA would be utilized for various sites and organizations, it would be desirable to see this feature added. Also, printing of trends/graphs is required for reporting and condition assessment/analysis purposes.

TABLE 3-5A FILTERCHECK/IDA WEAR STATE ASSESSMENT COMPARISON

Date	*MGB S/N*	*IDA Analysis*	*FilterCHECK Analysis*	*Manual FDA*
19-Jun-00	C-31	Normal	Normal	Normal
20-Jun-00	C-28	Monitor	Monitor	Normal
21-Jun-00	C-28	Monitor	Monitor	Normal
22-Jun-00	C-28	Normal	Normal	Normal
19-Jul-00	C-16	Normal	Normal	Normal
19-Jul-00	C-16	Monitor	Monitor	Normal
24-Jul-00	C-16	Normal	Normal	Normal
23-Jun-00	C-34	Monitor/Investigate	Investigate	Normal
19-Jul-00	C-34	Normal	Normal	Normal
19-Jul-00	C-34	Normal	Normal	Normal
17-Oct-00	C-34	Monitor/Investigate	Monitor	Normal
17-Oct-00	C-34	Normal	Normal	Normal
17-Oct-00	C-34	Normal	Normal	Normal
05-Jun-00	C-22	Normal	Normal	Normal
19-Jul-00	C-22	Normal	Normal	Normal
19-Jul-00	C-22	Normal	Normal	Normal
19-Jul-00	S109	Normal	Normal	Normal
19-Jul-00	S109	Normal	Normal	Normal
19-Jul-00	S109	Normal	Normal	Normal
25-Jul-00	S113	Monitor	Monitor	Monitor
25-Jul-00	S113	Normal	Normal	Monitor
25-Jul-00	S113	Normal	Normal	Monitor
10-Aug-00	C-12	Monitor	Monitor	Normal
10-Aug-00	C-12	Normal	Normal	Normal
08-Aug-00	C-12	Normal	Normal	Normal
28-Jul-00	516	Monitor	Monitor	Normal
31-Jul-00	516	Normal	Normal	Normal
04-Aug-00	516	Normal	Normal	Normal
24-Aug-00	C-40	Normal	Normal	Normal
24-Aug-00	C-40	Normal	Normal	Normal
24-Aug-00	C-40	Normal	Normal	Normal
26-Sep-00	C-38	Monitor	Monitor	Monitor
26-Sep-00	C-38	Normal	Normal	Monitor
26-Sep-00	C-38	Normal	Normal	Monitor
30-Aug-00	C-38	Monitor	Monitor	Normal
30-Aug-00	C-38	Normal	Normal	Normal
30-Aug-00	C-38	Normal	Normal	Normal
27-Sep-00	C-43	Normal	Normal	Normal
17-Oct-00	C-43	Normal	Normal	Normal
14-Sep-00	C-23	Normal	Normal	Normal
14-Sep-00	C-23	Normal	Normal	Normal
14-Sep-00	C-23	Normal	Normal	Normal
18-Sep-00	C-23	Normal	Normal	Normal
18-Sep-00	C-23	Normal	Normal	Normal
18-Sep-00	C-23	Normal	Normal	Normal
26-Sep-00	C-38	Normal	Normal	Monitor
26-Sep-00	C-38	Normal	Normal	Monitor
26-Sep-00	C-38	Normal	Normal	Monitor
30-Oct-00	C-38	Normal	Monitor	Normal
30-Oct-00	C-38	Normal	Normal	Normal
30-Oct-00	C-38	Normal	Normal	Normal
03-Nov-00	C-24	Normal	Normal	Normal
03-Nov-00	C-24	Normal	Normal	Normal
03-Nov-00	C-24	Normal	Normal	Normal
26-Jan-01	C-29	Investigate	Investigate	Normal
26-Jan-01	C-29	Investigate	Investigate	Normal
26-Jan-01	C-29	Investigate	Monitor	Normal
17-Jan-01	S110	Investigate	Normal	Monitor
17-Jan-01	S110	Normal	Normal	Monitor
Date	**Engine S/N**	**IDA Analysis**	**FilterCHECK Analysis**	**Manual FDA**
07 Nov-00	275025	Normal	Monitor	Normal
02-Nov-00	275050	Normal	Normal	Normal
19-Jul-00	275052	Investigate	Normal	Normal
12-Jan-01	275134	Investigate	Normal	Normal
12-Jan-01	275099	Investigate	Monitor	Normal
07-Nov-00	275170	Monitor	Monitor	Normal

The results indicate that FilterCHECK and IDA are equally capable in their ability to accurately reflect component condition in CH124 main gearboxes and turbines. FilterCHECK accomplishes this while also requiring minimal maintenance, training and sampling time.

TABLE 3-5B: COMPARISION OF DREA / IDA/ FILTERCHECK MGB FILTER FDA RESULTS

	Before 1-November-2000		*After 1-November-2000*	
	No.	%	No.	%
Agree	3	50	1	33
Disagree	3	50	2	67

TABLE 3-5C: COMPARISION OF IDA / FILTERCHECK MGB FILTER FDA RESULTS

	Before 1-November-2000		*After 1-November-2000*	
	No.	%	No.	%
Agree	50	100	7	78
Disagree	0	0	2	22

TABLE 3-5D: COMPARISION OF IDA / FILTERCHECK ENGINE FILTER FDA RESULTS

	Before 1-November-2000		*After 1-November-2000*	
	No.	%	No.	%
Agree	0	0	2	33
Disagree	0	0	4	67

TABLE 3-6 FILTERCHECK/IDA REPORTING FEATURES COMPARISON (BASED ON SAMPLE REPORTS IN APPENDIX C & D)

Report Feature	*Lube Analyst*	*IDA*	*Note:*
Heading	Yes	Yes	Desirable Feature
Sample ID	Yes	Yes	Desirable Feature
Sample Date	Yes	Yes	Desirable Feature
Organization and Work Site	Yes	No	Desirable Feature
Expert System Diagnosis	Yes	Yes	Desirable Feature
User Recommendation / Input	Yes	Yes	Desirable Feature
Tabulated Results	Yes	Yes	Desirable Feature
Trending Capability	Yes	Yes	Optional Feature
Graphing Capabilities	Yes	Yes	Desirable Feature
Printing Capabilities	Yes	Yes (but not for graphing)	Desirable Feature

Unfortunately, IDA is sensitive to the operator and its environment. Assessment of IDA has been problematic with technical issues from the camera white balance, to undesired sample movement due to the abrupt motion of the servos. Even though IDA is capable of assessing component condition, these technical issues make IDA, at present, an unlikely candidate for first-line FDA.

4. Conclusions/Recommendations

Based on the observations, the following conclusions can be made on FDA as a first-line IHM tool:

- The FilterCHECK is a reliable filter debris extraction and analysis tool for use by first-line maintenance technicians. When coupled with Lube Analyst, it provides a quick and accurate assessment of equipment health.
- The IDA is a laboratory instrument that has potential but requires more development in particle morphology identification and reporting.
- The IDA is an accurate FDA analysis tool but is sensitive to the operator and its environment, and exhibits a number of technical issues. Therefore, the IDA is an unlikely candidate for first-line FDA.

Based on the observations, the following recommendations can be made on FDA as a first-line IHM tool:

- Reduction of the FilterCHECK cycle time should be investigated in order to determine the optimum filter cleaning time.
- FilterCHECK statistical condition indicator guidelines for the "Normal" wear regime (Tables 3-1 and 3-2) should be applied to all wear regimes of the CH124 MGB.
- FilterCHECK statistical condition indicator guidelines (Table 3-3), based on all FilterCHECK data irrespective of wear regime, should be applied to the T58 Engine.
- As more data becomes available, the wear regimes of the T58 Engine, and the FilterCHECK statistical condition indicator guidelines for each wear regime of the CH124 MGB and T58 Engine should be reassessed.
- The data in the largest bin size is consistently nil, and therefore should be deleted as a condition indicator parameter.
- The FilterCHECK should be "field-trialed" to assess its design, operator training requirements, and minimal sampling time.
- The following are some features of IDA that require improvement. These may help to improve IDA's capabilities as a 2nd line tool, but the sensitivity of the equipment make it an unlikely field FDA candidate given the demands of maritime environment.
    - A method of ensuring that the patch/slide is placed in the same position each time would greatly enhance sample repeatability. The current method of aligning the microscope light to the back of the patch creates variability in IDA results.

- The stepwise movement of the control servos that move the platform, on which the patch/slide rests, are sufficiently abrupt (jerky) to cause the slide to move relative to the platform. A method of securing the slide to the platform should be implemented in parallel with repeatable positioning.

- The stitch size should be reviewed as a large percentage of the patch is not scanned with the current 9x12 frame. A 13x17 frame seems more appropriate for the patches used at the 12 AMS IHM Shop.

- The fibre optic lights should be permanently mounted and position fixed to remove variability in shadows around the particles. This ultimately affects repeatability of particle size recognition as light intensity changes each time the technician attempts to optimize the position of the fibre optic lights.

- A process for regularly checking the white balance of the camera. There is difficulty in obtaining a consistent colour pallet from the camera. This ultimately affects repeatability of wear type pattern recognition as the colour pallet varies from sample to sample.

- Some investigation into trending and graphing of the first sample for a component is required. Frequently the IDA condition indicator software has provided a wear state assessment of "Investigate" in this situation, due to the falsely detected sharp increase in wear rate.

- As IDA could be utilized at various sites and/or organizations, it would be desirable to see "Organization" and "Work Site" added to the IDA reporting. Also, printing of trends/graphs for reporting purposes is required.

Annex A: Raw FilterCHECK Data

DATE	A/C	MGB S/N	Remarks	#1 LUBE	#2 LUBE	Q Pump	Lubs Analyst	Eng S/N	TSN Hrs	TSO Hrs	Filter Hrs.	FE 100 (mg)	FE 300 (mg)	FE 500 (mg)	FE 914 (mg)	FE 100 (#)	FE 300 (#)	FE 500 (#)	FE 914 (#)	NFE 330 (#)	NFE 500 (#)	NFE 750 (#)	NFE 1000 (#)	FE (mg)	FE (mls/h)	Total FE (#)	FE #/Hr	Total NFE (#)	NFE #/Hr
19-Jun-00	410	C-31		X					8068.1	1412.1	122.7	49.4	10.7	0	0	1511	41	0	0	0	0	0	0	60.1	10.9	1552	336	0	0
24-Jul-00	410	C-31	Retained Debris		X				8068.1	1412.1	122.7	0.4	0.8	0	0	11	3	0	0	0	0	0	0	1.1	25.7	14	3.4	0	0
24-Jul-00	410	C-31	Retained Debris			X			8068.1	1412.1	122.7	0.3	0	0	0	8	0	0	0	0	0	0	0	0.3	4.3	8	1.92	0	0
21-Aug-00	410	C-31		X								1.4	0.3	0	0	43	1	0	0	0	0	0	0	1.7	0	44	10	0	0
19-Jun-00	408						Normal	27505.2	9426.6	1467.3		2.8	0	0	0	85	0	0	0	0	0	0	0	10	2.8	85	0	0	0
24-Jul-00	408		Retained Debris					27505.2	9426.6	1467.3		0.1	0	0	0	3	0	0	0	0	0	0	0	0.1	1.8	3	54	0	0
20-Jun-00	428	C-28	DREA #1	X			Monitor		8418	668	300	49.4	10.7	0	0	1511	41	0	0	0	0	0	0	60.1	11.3	1552	328	0	0
21-Jun-00	428	C-28			X		Monitor		8418	668	300	60.8	30.6	8.7	0	1861	117	6	0	0	0	0	0	100	27.2	1984	665	0	0
23-Jul-00	428	C-28	Retained Debris		X				8418	668	300	3.1	0	0	0	96	0	0	0	0	0	0	0	3.1	83.8	96	2562	0	0
22-Jun-00	428	C-28				X	Normal		8418	668	300	2.5	0.3	1.4	0	77	1	1	0	0	0	0	0	4.2	0.2	79	4	0	0
24-Jul-00	428	C-28	Retained Debris			X						0.4	0	0	0	11	0	0	0	0	0	0	0	0.4	5.6	11	264	0	0
19-Jul-00	426	C-16	DREA #1	X					8598.6	120.2	120.2	12.4	3.1	0	0	380	12	0	0	0	0	0	0	15.6	5.1	392	114	0	0
19-Jul-00	426	C-16			X		Monitor		8598.6	120.2	120.2	35.4	8.1	5.8	0	1083	31	4	0	2	0	0	0	49.3	9	1118	33	2	0
24-Jul-00	426	C-16	Retained Debris		X				8598.6	120.2	120.2	5.9	0.5	0	0	180	2	0	0	0	0	0	0	6.4	180	182	5115	0	0
24-Jul-00	426	C-16				X	Normal		8598.6	120.2	120.2	1.2	0.8	0	0	37	3	0	0	0	0	0	0	2	0.2	40	6	0	0
24-Jul-00	426	C-16	Retained Debris			X			8598.6	120.2	120.2	0.2	0	0	0	5	0	0	0	0	0	0	0	0.2	3.3	5	138	0	0

DATE	A/C	MGB S/N	Remarks	#1 LUBE	#2 LUBE	Q Pump	Lube Analysis	Eng S/N	TSN Hrs	TSO Hrs	Filter Hrs.	FE 100 (mg)	FE 300 (mg)	FE 500 (mg)	FE 914 (mg)	FE 100 (#)	FE 300 (#)	FE 500 (#)	FE 914 (#)	NFE 330 (#)	NFE 500 (#)	NFE 750 (#)	NFE 1000 (#)	FE (mg)	FE (mils/h)	Total FE (#)	FE #/Hr	Total NFE (#)	NFE #/Hr
23-Jun-00	403	C-34	DREA #1	X			Investigate		7885.8	213.1	50	79.4	34.2	8.7	0	2429	131	6	0	0	0	0	0	122	0	2566	0	0	0
19-Jul-00	403	C-34			X		Normal		7885.8	213.1	50	36.8	5.2	1.4	0	1126	20	1	0	0	0	0	0	43.5	12.2	1147	330	0	0
24-Jul-00	403	C-34	Retained Debris		X				7885.8	213.1	50	0.4	0	0	0	2	0	0	0	0	0	0	0	0.4	1.6	2	48	0	0
19-Jul-00	403	C-34				X	Normal		7885.8	213.1	50	0.2	0.3	0	0	6	1	0	0	0	0	0	0	0.5	0	7	0	0	0
24-Jul-00	403	C-34	Retained Debris			X			7885.8	213.1	50	0.4	0	0	0	3	0	0	0	0	0	0	0	0.4	4.7	7	132	0	0
17-Oct-00	403	C-34		X					7977.7	305	14.4	23.1	6	0	0	706	23	0	0	0	0	0	0	29.1	43.6	729	1109	0	0
17-Oct-00	403	C-34			X				7977.7	305	14.4	3.7	0.5	2.9	0	114	2	2	0	0	0	0	0	7.1	4.5	118	714	0	0
17-Oct-00	403	C-34				X			7977.7	305	14.4	0.4	0	0	0	11	0	0	0	0	0	0	0	0.4	2.5	11	69	0	0
05-Jun-00	405	C-22		X			Normal		8123.6	792.2	310.8	16.7	1.8	0	0	512	7	0	0	0	0	0	0	18.6	0	519	0	0	0
24-Jul-00	405	C-22	Retained Debris	X					8123.6	792.2	310.8	0.1	0	0	0	2	0	0	0	0	0	0	0	0.1	2.2	2	66	0	0
19-Jul-00	405	C-22	DREA# 2		X		Normal		8123.6	792.2	310.8	23.6	1.8	0	0	721	7	0	0	0	0	0	0	26.4	3.5	728	660	0	0
19-Jul-00	405	C-22				X	Normal		8123.6	792.2	310.8	0.3	0	0	0	10	0	0	0	0	0	0	0	0.3	0	10	0	0	0
24-Jul-00	405	C-22	Retained Debris			X			8123.6	792.2	310.8	0	0	0	0	1	0	0	0	0	0	0	0	0	0.8	1	25	0	0
19-Jul-00	437	S109		X			Normal		7076.7	844.8	237	12.9	3.9	1.4	0	395	15	1	0	0	0	0	0	18.3	3.9	411	78	0	0
24-Jul-00	437	S109	Retained Debris	X					7076.7	844.8	237	2.6	0	0	0	81	0	0	0	0	0	0	0	2.6	15.9	81	486	0	0
19-Jul-00	437	S109	DREA# 2		X		Normal		7076.7	844.8	237	6.7	2.4	2.9	0	204	9	2	0	0	0	0	0	11.9	0	215	0	0	0
19-Jul-00	437	S109				X	Normal		7076.7	844.8	237	1.6	0.5	0	0	48	2	0	0	0	0	0	0	2.1	0.5	50	6	0	0
24-Jul-00	437	S109	Retained Debris			X			7076.7	844.8	237	0.2	0	0	0	5	0	0	0	0	0	0	0	0.2	3.4	5	102	0	0
25-Jul-00		S113	Aero	X			Monitor		5835	674.1	112	47	34.8	1.4	0	1439	433	1	0	0	1	0	0	83.2	22.9	1573	406	1	0

DATE	A/C	MGB S/N	Remarks	#1 LUBE	#2 LUBE	Q Pump	Lube Analysis	Eng S/N	ESN Hrs	TSO Hrs	Filter Hrs.	DI 100 (mg)	DI 300 (mg)	DI 500 (mg)	DI 914 (mg)	DI 100 (#)	DI 300 (#)	DI 500 (#)	DI 914 (#)	NDI 330 (#)	NDI 500 (#)	NDI 750 (#)	NDI 1000 (#)	DI (mg)	DI (mils/hr)	Total DI (#)	DI /Hr	Total NDI (#)	NDI /Hr
25-Jul-00		S133	Auto		X		Normal		5835	674.1	112	1.6	0.5	0	0	50	2	0	0	14	1	0	0	2.2	2	52	10	15	30
25-Jul-00		S133	Auto			X	Normal		5835	674.1	112	1.9	0.3	0	0	57	1	0	0	0	0	0	0	2.1	0.6	58	10	0	0
10-Aug-00	438	C-12			X			Monitor		8708.3	1440.8	300.3	50.8	17.5	10.1	0	1556	67	7	0	0	0	0	0	78.5	3.8	1630	102	0	0
10-Aug-00	438	C-12				X		Normal		8708.3	1440.8	300.3	1.9	0	0	0	58	0	0	0	0	0	0	0	1.9	0.2	58	6	0	0
08-Aug-00	438	C-12					X			8708.3	1440.8	300.3	3.4	0.5	0	0	105	2	0	0	0	0	0	0	4	1	107	30	0	0
28-Jul-00	406	526			X			Monitor		6911.4	777.6	295.7	25.5	7.3	1.4	0	788	28	1	0	0	0	0	0	34.2	0.8	809	24	0	0
31-Jul-00	406	526				X		Normal		6911.4	777.6	295.7	11.5	3.9	1.4	0	414	15	1	0	0	0	0	0	15.9	0.5	430	13	0	0
04-Aug-00	406	526					X	Normal		6911.4	777.6	295.7	0.6	0	0	0	26	0	0	0	1	0	0	0	0.8	0.2	26	6	1	0
24-Aug-00		C-40			X					6691	0	0	3.6	1	0	0	116	4	0	0	0	0	0	0	4.8	1	120	30	0	0
24-Aug-00		C-40				X				6691	0	0	7.3	1.6	0	0	224	8	0	0	0	0	0	0	8.9	53.7	230	1373	0	0
24-Aug-00		C-40					X			6691	0	0	0.4	0	0	0	12	0	0	0	0	0	0	0	0.4	5	12	94	0	0
26-Sep-00	404	C-38			X					7583.1	130.1	130.1	61.3	24	21.6	0	1870	92	15	0	0	0	1	0	107	16	1985	492	1	0
26-Sep-00	404	C-38				X				7583.1	130.1	130.1	3.2	0.3	0	0	97	1	0	0	0	0	0	0	3.4	1	98	30	0	0
26-Sep-00	404	C-38					X			7583.1	130.1	130.1	4.7	0.8	2.9	0	148	3	2	0	0	0	0	0	8.4	0.2	150	6	0	0
30-Oct-00	404	C-38			X					7697.7	244.7	114.6	42.1	6.5	0	0	1286	50	0	0	0	0	0	0	48.6	6.4	1336	256	0	0
30-Oct-00	404	C-38				X				7697.7	244.7	114.6	4.9	0.3	0	0	137	3	0	0	0	0	0	0	5.2	2.4	140	72	0	0
30-Oct-00	404	C-38					X			7697.7	244.7	114.6	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0
27-Sep-	429	C-13				X				7579.2	1595.1	46.2	16	1.6	0	0	5.8	491	6	0	0	1	0	0	0	23.4	9	495	276	0	0

DATE	A/C	MGB S/N	Remarks	#1 LUBE	#2 LUBE	Q Pump	Lube Analysis	Eng S/N	ESN Hrs	ESO Hrs	Filter Hrs.	FE 100 (mg/l	FE 300 (mg)	FE 500 (mg)	FE 914 (mg)	FE 100 (ft)	FE 300 (ft)	FE 500 (ft)	FE 914 (ft)	NFE 330 (ft)	NFE 500 (ft)	NFE 750 (ft)	NFE 1000 (ft)	FE (mg)	FE (mh/h)	Total FE (ft)	FE /Hr	Total NFE (ft)	NFE /Hr
00																													
18-Oct-00	429	C-43		X					7612.7	1631.6	79.7	14.6	0.5	0	0	447	2	0	0	0	0	0	0	35.1	5.3	449	16.2	0	0
14-Sep-00	417	C-23		X					7981.9	1	0	6.7	1.6	0	0	204	6	0	0	0	0	0	0	8.2	1	210	30	0	0
14-Sep-00	417	C-23			X				7981.9	1	0	4.5	0.8	0	0	139	3	0	0	0	0	0	0	5.3	0.8	142	24	0	0
14-Sep-00	417	C-23				X			7981.9	1	0	0.1	0	0	0	3	0	0	0	0	0	0	0	0.1	0.6	3	15	0	0
18-Sep-00	417	C-23		X					7981.9	0	1	0.5	0	0	0	25	0	0	0	0	0	0	0	0.5	0.3	25	12	0	0
18-Sep-00	417	C-23			X				7981.9	0	1	2.5	0	0	0	85	0	0	0	0	0	0	0	2.5	0.2	85	6	0	0
18-Sep-00	417	C-23				X			7981.9	0	1	0.1	0	0	0	4	0	0	0	0	0	0	0	0.1	0.6	4	15	0	0
03-Nov-00	407	C-24		X					8478.2	314.5	276.7	33.1	2.6	1.4	0	1019	10	1	0	0	0	0	0	37.4	5.9	1030	198	0	0
03-Nov-00	407	C-24			X				8478.2	314.5	276.7	12.5	1.3	0	0	384	5	0	0	0	0	0	0	13.9	1.8	389	54	0	0
03-Nov-00	407	C-24				X			8478.2	314.5	276.7	0.5	0.0	0	0	14	2	0	0	0	0	0	0	1	0	16	0	0	0
07-Nov-00									275170	8633.8	579.3	17.6	7.3	1.3	0	222	5	0	0	0	0	0	0	8.6	2	227	66	0	0
07-Nov-00									275025	8018.4	414.2	414.2	7.8	7.1	2.6	0	240	27	2	0	0	0	0	17.8	5.1	269	72	0	0
07-Dec-00									275097	7931.2	209.3	209.3	9.7	3.9	2.6	0	295	15	2	0	0	0	0	16.5	3.9	315	126	0	0
07-Dec-00									275057	8047.6	239.6	239.6	9.6	2.6	0	0	294	10	0	0	0	0	0	12.2	9.0	304	193	0	0
27-Nov-00	424	S-110		X					7767.9	1290.4	300	23.0	2.1	0	0	727	8	0	0	0	0	0	0	25.8	6.1	735	156	0	0
27-Nov-00	424	S-110			X				7767.9	1290.4	300	17.3	1.5	1.4	0	575	7	1	0	0	0	0	0	20.3	5	586	468	0	0
27-Nov-00	424	S-110				X			7767.9	1290.4	300	4.4	0.8	1.4	0	135	1	1	0	0	0	0	0	6.6	5.2	139	126	0	0

DATE	A/C	MGB S/N	Remarks	#1 LUBE	#2 LUBE	Q Pump	Lube Analyst	Eng S/N	TSN Hrs	TSO Hrs	Filter Hrs	FE 100 (mg)	FE 360 (mg)	FE 500 (mg)	FE 914 (mg)	FE 100 (#)	FE 300 (#)	FE 500 (#)	FE 914 (#)	NFE 330 (#)	NFE 500 (#)	NFE 750 (#)	NFE 1000 (#)	FE (mg)	FE (mls/h)	Total FE (#)	FE #/Hr	Total NFE (#)	NFE #/Hr
05-Dec-00	440	S-103		X					8895.1	2	2	4.7	1.3	0	0	143	5	0	0	0	0	0	0	6	1.8	148	5.6	0	0
05-Dec-00	440	S-103			X				8895.1	2	2	3.3	0.8	0	0	161	3	0	0	0	0	0	0	4.1	0.1	164	186	0	0
05-Dec-00	440	S-103				X			8895.1	2	2	0.1	0.3	0	0	2	0	0	0	0	0	0	0	0.3	0	3	0	0	0
06-Dec-00	421	C-35		X					8514.1	555.6	363.5	10.7	1	0	0	326	4	0	0	0	0	0	0	11.7	7.4	340	8.2	0	0
06-Dec-00	421	C-35			X				8514.1	555.6	363.5	13.5	1.8	0	0	407	5	0	0	0	0	0	0	14.8	7.1	412	210	0	0
06-Dec-00	421	C-35				X			8514.1	555.6	363.5	1.9	0.5	0	0	59	2	0	0	0	0	0	0	2.4	4.9	61	130	0	0
07-Dec-00									275026	7876.5	1416.5	170.9	5.9	3.7	0	0	181	14	0	0	1	0	0	0	9.6	2.5	195	36	1	0
07-Dec-00									275025	8018.4	114.2	7.1	7.1	2.9	0	240	27	2	0	0	0	0	0	17.8	5.1	269	72	0	0
01-Dec-00									275036	8676.1	1415.3	30	0.3	0	0	0	13	0	0	0	0	0	0	0	0.4	2.5	13	78	0	0
01-Dec-00									275036	8676.1	1415.3	17	0.8	0	0	0	23	0	0	0	0	0	0	0	0.8	0	23	0	0	0
01-Dec-00									275040	8335.2	534.3	200	3.6	1.6	0	0	310	6	0	0	0	0	0	0	5.2	2.5	116	36	0	0
01-Dec-00									275053	9320.7	0	5	0.8	1	0	0	25	4	0	0	0	0	0	0	1.9	16.8	29	252	0	0
01-Dec-00									275110	1643.4	948.3	288	5.7	2.1	0	0	173	8	0	0	2	0	0	0	7.7	5.7	181	132	2	0
05-Dec-									275135	8463.7	418	700	1.5	2.1	0	0	47	8	0	0	0	0	0	0	3.6	0.2	55	4	0	0

DATE	A/C	MGB SN	Remarks	#1 LUBE	#2 LUBE	Q Pump	Lube Analysis	Eng SN	TSN Hrs	TSO Hrs	Filter Hrs.	DI 100 (mg)	DI 300 (mg)	DI 500 (mg)	DI 914 (mg)	DI 100 (ml)	DI 300 (ml)	DI 500 (ml)	DI 914 (ml)	NDI 330 (ml)	NDI 500 (ml)	NDI 750 (ml)	NDI 1000 (ml)	PQ (mg/l)	DE (mmh)	Total DI (ml)	DI #/Hr	Total NDI (ml)	NDI #/Hr
00																													
05-Dec-00									275135	8394.2	348.5	147.6	2.2	1.6	5.8	0	66	6	4	0	0	0	0	0	9.5	0.6	76	18	0	0
01-Dec-00									275139	9222.8	1986.4	153.4	3.4	0	0	0	135	0	0	0	0	0	0	0	0	3.4	0.2	135	6	0	0
07-Nov-00									275050	8091.8	1068	162.9	2.4	0	0	0	72	0	0	0	0	0	0	0	0	2.4	1.2	72	36	0	0
06-Dec-00									275015	9288.8	493.4	70	1.1	0.8	0	0	34	3	0	0	0	0	0	0	0	1.9	0.6	37	18	0	0
03-Dec-00									275015	9219.3	423.9	147.6	1.7	0.3	1.4	0	52	1	1	0	0	0	0	0	0	3.4	1.8	54	54	0	0
18-Jan-01	430	A26		X						8424.3	1	1	7.6	0.8	0	0	233	3	0	0	0	0	0	0	8.4	1.4	236	42	0	0
17-Jan-01	424	S110		X						7817	1339.5	49.2	4.5	0.5	1.4	0	139	2	1	0	0	0	0	0	6.5	0.6	142	18	0	0
26-Jan-01	431	A29	Chip Light	X						7134	11	11	5.9	3.7	1.4	0	182	14	1	0	0	0	0	0	11	0.8	192	12	0	0
29-Jan-01	408	S115		X						7219.9	1365.2	276.4	36.4	2.1	0	0	501	8	0	0	0	0	0	0	38.5	661.2	5509	1032	0	0
17-Jan-01	424	S110			X					7817	1339.5	49.2	2.4	0.5	0	0	77	2	0	0	0	0	0	0	3	1	79	36	0	0
26-Jan-01	431	A29	Chip Light		X					7134	11	11	4.9	0.5	0	0	150	2	0	0	0	0	0	0	5.4	0.4	152	12	0	0
29-Jan-01	408	S115			X					7219.9	1365.2	276.4	6	0.8	0	0	185	3	0	0	0	0	0	0	6.8	3.6	1888	1000	0	0
17-Jan-01	424	S110				X				7817	1339.5	49.2	0.3	0.3	0	0	9	1	0	0	0	0	0	0	0.6	0	10	18	0	0
26-Jan-01	431	A29	Chip Light			X				7134	11	11	0.3	0.8	0	0	30	3	0	0	0	0	0	0	1.1	2	33	18	0	0
29-Jan-01	408	S115				X				7219.9	1365.2	276.4	0.7	0	0	0	22	0	0	0	0	0	0	0	0.7	4.9	22	143	0	0

Annex B: Raw IDA Data

Raw IDA Data Date	A/C	MGB S/N	Eng S/N	Remarks	#1 LUBE	#2 LUBE	Q Pump	CLASS 1	CLASS 2	CLASS 3	CLASS 4	IDA	Cut	Rub	Slide	Fatigue	Total	Unknown	Reject Rate
19-Jun-00	410	C-31			X							Normal							
24-Jul-00	410	C-31		Retained Debris		X													
24-Jul-00	410	C-31		Retained Debris			X	1.728	0.896	0.024	0.008	Normal	19	15	0	0	67	33	49.25%
21-Aug-00	410	C-31			X			1.728	0.896	0.024	0.008	Normal							
19-Jun-00	408		275052					17.742	2.366	0	0	Normal	15	8	0	2	44	19	43.18%
02-Nov-00	437		275050					0.221	0.362	0.012	0.006		15	2	1	1	33	14	42.42%
20-Jun-00	428	C-28		DREA #1	X							Monitor							
21-Jun-00	428	C-28				X		0.877	0.557	0.023	0.003	Monitor	11	3	0	2	148	132	89.19%
24-Jul-00	428	C-28		Retained Debris		X													
22-Jun-00	428	C-28					X	0.15	0.317	0.013	0.003	Normal	5	2	0	3	67	57	85.07%
24-Jul-00	428	C-28		Retained Debris			X												
19-Jul-00	426	C-16		DREA#1	X							Normal							
19-Jul-00	426	C-16				X		0.824	1.206	0.017	0.008	Monitor	11	14	0	2	131	104	79.39%
24-Jul-00	426	C-16		Retained Debris		X													
24-Jul-00	426	C-16					X	2.77	0.532	0.008	0	Normal	9	13	0	0	40	18	45.00%
24-Jul-00	426	C-16		Retained Debris			X												
23-Jun-00	403	C-34		DREA #1	X							Monitor Investigating							
19-Jul-00	403	C-34				X		0.42	1.6	0.16	0.12	Normal	7	3	0	1	39	28	71.79%
24-Jul-00	403	C-34		Retained Debris		X													
19-Jul-00	403	C-34					X	-0.24	0.52	0.2	0.22	Normal	5	2	0	1	16	8	50.00%
24-Jul-00	403	C-34		Retained Debris			X												
17-Oct-00	403	C-34			X							Monitor							

Raw IDA Data Date	A/C	MGB S/N	Eng S/N	Remarks	#1 LUBE	#2 LUBE	Q Pump	CLASS 1	CLASS 2	CLASS 3	CLASS 4	IDA	Cut	Rub	Slide	Fatigue	Total	Unknown	Reject Rate
												Investigate							
17-Oct-00	403	C-34				X						Normal							
17-Oct-00	403	C-34					X					Normal							
05-Jun-00	405	C-22			X			0.737	0.602	0.023	0.019	Normal	13	24	0	12	169	120	71.01%
24-Jul-00	405	C-22		Retained Debris	X														
19-Jul-00	405	C-22		DREA#2		X						Normal							
19-Jul-00	405	C-22					X	0.286	0.351	0.003	0	Normal	2	0	0	2	11	7	63.64%
24-Jul-00	405	C-22		Retained Debris			X												
19-Jul-00	437	S109			X							Normal							
24-Jul-00	437	S109		Retained Debris	X														
19-Jul-00	437	S109		DREA#2		X		1.924	0.962	0.093	0.004	Normal	42	24	0	8	242	168	69.42%
19-Jul-00	437	S109					X	0.363	0.477	0	0	Normal	6	0	0	0	20	14	70.00%
24-Jul-00	437	S109		Retained Debris			X												
25-Jul-00		S113		Acro	X							Monitor							
25-Jul-00		S113		Acro		X						Normal							
25-Jul-00		S113		Acro			X					Normal							
10-Aug-00	438	C-12			X			0.623	0.739	0.023	0	Monitor	16	15	0	9	198	158	79.80%
10-Aug-00	438	C-12				X		0.09	0.193	0.043	0.043	Normal	6	2	1	2	37	26	70.27%
08-Aug-00	438	C-12					X					Normal							
28-Jul-00	406	516			X			1.016	0.549	0	0	Monitor	92	0	0	0	105	13	12.38%
31-Jul-00	406	516				X		0.379	0.689	0.057	0.01	Normal	36	13	2	8	187	128	68.45%
04-Aug-00	406	516					X	0.064	0.162	0	0	Normal	8	2	0	0	22	12	54.55%
16-Aug-00	406	516			X			2.288	1.381	0.066	0.004		161	24	6	9	386	186	48.19%
16-Aug-00	406	516			X			1.907	1.268	0.097	0		127	29	1	11	348	180	51.72%
16-Aug-00	406	516			X			2.51	1.506	0.066	0.004		128	24	4	5	322	161	50.00%
24-Aug-00		C-40			X							Normal							
24-Aug-00		C-40				X						Normal							

Raw IDA Data Date	A/C	MGB S/N	Eng S/N	Remarks	#1 LUBE	#2 LUBE	Q Pump	CLASS 1	CLASS 2	CLASS 3	CLASS 4	IDA	Cut	Rub	Slide	Fatigue	Total	Unknown	Reject Rate
24-Aug-00		C-40										Normal							
26-Sep-00	404	C-38			X			4.904	1.922	0.085	0.031	Monitor	46	29	2	5	253	171	67.59%
26-Sep-00	404	C-38				X		0.154	0.899	0.108	0.061	Normal	19	3	0	1	90	67	74.44%
26-Sep-00	404	C-38					X	0.638	0.961	0.077	0.031	Normal	37	7	0	3	71	24	33.80%
30-Oct-00	404	C-38			X			1.038	1.143	0.079	0.009	Monitor	1	9	0	1	132	121	91.67%
30-Oct-00	404	C-38				X		0.113	0.332	0	0	Normal	2	2	0	1	30	25	83.33%
30-Oct-00	404	C-38					X	0.733	0.532	0.017	0	Normal	16	7	0	2	45	20	44.44%
27-Sep-00	429	C-43				X		9.416	9.242	0.238	0.043	Normal	86	12	5	9	422	310	73.46%
17-Oct-00	429	C-43			X			4.793	2.748	0.201	0.05	Normal	27	14	2	9	233	181	77.68%
28-Jul-00		C-26			X			401	233	1	0		135	7	0	3	161	16	9.94%
15-Aug-00		C-26			X			227	194	10	0		51	17	0	14	165	83	50.30%
14-Sep-00	417	C-23			X							Normal	37	11	0	6	140	86	61.43%
14-Sep-00	417	C-23				X		2	86	17	2	Normal	16	7	0	0	56	33	58.93%
14-Sep-00	417	C-23					X	-26	40	12	8	Normal	3	2	0	0	11	6	54.55%
18-Sep-00	417	C-23			X			-55	82	13	5	Normal	3	1	0	0	11	7.00	63.64%
18-Sep-00	417	C-23				X		-16	64	15	5	Normal	15	0	1	1	39	22	56.41%
18-Sep-00	417	C-23					X	-76	127	14	4	Normal	9	2	0	0	16	5	31.25%
3-Nov-00	407	C-24			X			1.041	0.665	0.036	0.004	Monitor	54	12	0	8	173	99	57.23%
3-Nov-00	407	C-24				X		1.218	1.088	0.025	0.004	Normal	55	19	0	2	296	220	74.32%
3-Nov-00	407	C-24					X	0.112	0.036	0	0	Normal	0	1	0	0	5	4	80.00%
7-Nov-00			275170					0.312	0.766	0.057	0	Monitor	10	19	0	5	179	165	75.54%
7-Nov-00			275025					0.096	0.377	0.035	0	Monitor	10	1	0	1	30	18	60.00%
7-Dec-00			275097									Monitor							
7-Dec-00			275057									Monitor							
27-Nov-00	424	S-110			X							Monitor							
27-Nov-00	424	S-110				X						Normal							
27-Nov-00	424	S-110					X					Normal							
5-Dec-00	440	S-103			X							Normal							
5-Dec-00	440	S-103				X						Normal							

Raw IDA Data Date	A/C	MGB S/N	Eng S/N	Remarks	#1 LUBE	#2 LUBE	Q Pump	CLASS 1	CLASS 2	CLASS 3	CLASS 4	IDA	Cut	Rub	Slide	Fatigue	Total	Unknown	Reject Rate
5-Dec-00	440	S-103					X					Normal							
6-Dec-00	421	C-35			X							Normal							
6-Dec-00	421	C-35				X						Normal							
6-Dec-00	421	C-35					X					Normal							
1-Dec-00			275026									Monitor							
25-Oct-00			275025					0.096	0.377	0.035	0	Monitor							
1-Dec-00			275036									Normal							
1-Dec-00			275036									Normal							
1-Dec-00			275040									Normal							
1-Dec-00			275053									Normal							
1-Dec-00			275110									Monitor							
5-Dec-00			275135									Normal							
5-Dec-00												Normal							
29-Nov-00			275139									Normal							
2-Nov-00			275050					0.221	0.362	0.012	0.006	Normal							
6-Dec-00			275015									Normal							
5-Dec-00			275015									Normal							
12-Jan-01			275134					0.218	0.146	0	0	Investigate	6	9	0	0	38	23	60.53
12-Jan-01			275099					0.318	0.303	0.01	0.005	Normal	30	0	0	0	55	25	45.45
17-Jan-01	424	S110			X			2.541	1.829	0.183	0.02	Investigate	19	4	0	0	96	73	76.04
17-Jan-01	424	S110				X		0.549	0.711	0.02	0	Normal	9	1	0	0	33	23	69.7
26-Jan-01	431	C29			X			9.818	6.545	0.273	0.091	Investigate	17	0	2	0	74	55	74.32
26-Jan-01	431	C29				X		0.727	2.182	0.091	0	Investigate	4	0	1	0	14	9	64.29
26-Jan-01	431	C29					X	1.364	2.182	0.455	0.091	Investigate	3	0	0	0	20	17	85

Annex C: Sample FilterCHECK "Lube Analyst Sample Report"

Lube Analyst Sample Summary Report
Thursday, February 08, 2001 13:21

ATTN: Unknown Phone: Unknown Fax: Unknown

Sample ID:	00S00780	**Sample Date:**	05-Jul-2000 07:23
Organization:	12 WING	**Work Site:**	12 AMS
Equipment Type:	SEA KING	**Equipment ID:**	124405
System Type:	21000 MGB	**System ID:**	C22
Lube Class:	Lubricating Oil	**Lube Type:**	MIL-PRF-23699F, Class C/I

EXPERT SYSTEM DIAGNOSIS

Date Diagnosis Performed: Monday, August 28, 2000 11:21

Recommended Action(s): No action is required at this time.

Reason(s)/Evaluation(s): No action is required because no rules have been violated.

USER RECOMMENDATIONS

Date Entered: Not Available

by User: Not Available

Recommendations: None Entered

CF 730A Data Entry

PARAMETER VALUES

Parameter Name	Value	Units	Status
Time Since Overhaul	792.2	Hrs	---
Time Since Filter Change	310.8	Hrs	---

FilterCK3

PARAMETER VALUES

Parameter Name	Value	Units	Status
FilterCK3FeMass	0.3	Mg	Normal
FilterCK3FeCounts	10	particles	Normal
FilterCK3NFeCounts	0	particles	Normal
FilterCK3FeBin1	0	particles	Normal
FilterCK3FeBin2	0	particles	Normal

Annex D: Sample IDA "Filter Debris Analysis Report"

Filter Debris Analysis Report

Equip. Type: MGB
Serial#: C22
Patch Type: MAG
Pump#: p1
Insp. Lab: Tektrend International Inc.

Install Type: CH124
Register#: 405
Database Index: 203
Scan#: 1
Filter Date: Aug,09,2000

Data Acquisition Results

Acq./Pro. Frame Size: 640 x 480
Current Date: Aug,09,2000
File Name: c:\ida95\idatemp.tif
Save to the database: Yes

Acq. Mosaic Size: 9 x 12 .09 frames
Lens Type: 5x
Scale Down: No
Autofocus: No

Debris Analysis Results

Oil Screen Dev.: N/A
Size Mode Rejected: 40.00 um
Wear Mode Rejected: 100.00 um
Particle Coverage Area: 13.06 %
Average Par.# Per Frame: 0.01 par/h

Last Sample: 310.80 hours
Oil Change: 0.00 hours
New: 8123.60 hours
Over Haul: 792.20 hours
FDA Reason:

Ferrography Results:

Other Comments:

Size Analysis Results:

Class	Ranges (um)	Normal (par/h)	Monitor (par/h)	Results (par/h)
Class 1	40.0 -- 100.0	50.00	200.00	0.737
Class 2	100.0 -- 500.0	25.00	100.00	0.602
Class 3	500.0 -- 1000.0	1.00	5.00	0.023
Class 4	1000.0 -- ***	0.20	1.00	0.019
Class 5	0.0 -- 0.0	0.00	0.00	0.000
Class 6	0.0 -- 0.0	0.00	0.00	0.000
Class 7	0.0 -- 0.0	0.00	0.00	0.000
Class 8	0.0 -- 0.0	0.00	0.00	0.000

Maintenance Recommendation from Wear Size Analysis:

Normal
Component wear rate is normal.
Maintain regular monitoring schecule.

MGB/C22MAG/CH124-405 Page 1

Filter Debris Analysis Report

Trending Analysis Results:

	Record 1	Record 2	Record 3	Record 4	Record 5	Record 6	Record 7	Record 8
Date	09/08/00	09/08/00	09/08/00	09/08/00	09/08/00	09/08/00	09/08/00	09/08/00
CLA 1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.7368
CLA 2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.6017
CLA 3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0225
CLA 4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0193
CLA 5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CLA 6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CLA 7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CLA 8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Maintenance Recommendation from Trending Analysis:

No trend data in the database.
The trend analysis is unavailable.

Maintenance Recommendation from Wear Mode Analysis:

cut: 13 rub: 24 slide: 0 fatigue: 12
total: 169 unknown: 120 reject rate: 71.01 %

Comprehensive Conclusion:

Signature:

Annex E: Statistical Table for "Statistical Condition Monitoring Guidelines"

The following definitions should help with the interpretation of the results of statistical calculation presented in Tables E-1 through E-10. (The selection of +2 sigma and +4 sigma to establish "Monitor" and "Investigate" condition indicators, respectively, are derived from Reference [6].)

1. AVERAGE – the total of all the FDA data points in the sample, divided by the number of samples. This provides the average rate value for a given bin size or class.

2. COUNT – the number of MS EXCEL cells that contain numbers in the data list (i.e., excluding empty cells where data was unavailable). This provides the sample size for a given bin size or class.

3. STDEV – standard deviation of all the all the values for each FDA sample. This provides the deviation of the FDA sample value from the average value for a given bin size or class.

4. 2 SIGMA (Monitor) – AVERAGE value plus two times the STDEV. This value represents the upper guideline of expected variation in FDA sample value. This is an indication of good maintenance procedures and processes for alignment, balancing and general overhaul of a component.

5. 4 SIGMA (Investigate) – AVERAGE value plus four times the STDEV. This value represents the guideline of acceptable maintenance procedures and processes for alignment, balancing and general overhaul of a component. FDA sample value in excess of this value indicates the component is unserviceable, and requires maintenance action to confirm that the component is serviceable.

6. Coefficient of Variance (COV) LIMIT – the maximum acceptable population variance or scatter [6].

7. Coefficient of Variance (COV) – STDEV divided by the AVERGAE. This ratio provides an indication of the scatter in the data, and should be less than the COV LIMIT (See equation E-1) [6].

$$COV < 0.085\sqrt{COUNT} = COVLIMIT \qquad \text{Equation E-1}$$

TABLE E-1 - BREAK-IN WEAR (TSO < 280 HRS.): SUMMARY OF FILTERCHECK STATISTICAL CALCULATION FOR CH124 MGB LUBE#1

	FE Bin 1 (#/h)	FE Bin 2 (#/h)	FE Bin 3 (#/h)	FE Bin 4 (#/h)	NFE Bin 1 (#/h)	NFE Bin 2 (#/h)	NFE Bin 3 (#/h)	NFE Bin 4 (#/h)	FE Mass (mg/h)	FE Counts (#/h)	NFE Counts (#/h)
Average	9.61	0.34	0.04	0	0	0	0.00	0	0.46	9.99	0.00
Standard Deviation	5.81	0.32	0.07	0	0	0	0.00	0	0.35	6.13	0.00
Number of data points	3	3	3	3	3	3	3	3	3	3	3
COV Limit (%)	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
COV (%)	0.60	0.94	1.73	0	0	0	1.73	0	0.76	0.61	1.73
+2 Sigma	21.22	0.99	0.17	0	0	0	0.01	0	1.15	22.24	0.01
+4 Sigma	32.83	1.63	0.30	0	0	0	0.02	0	1.85	34.49	0.02

TABLE E-2 - NORMAL WEAR (280 HRS. < TSO < 1389 HRS.): SUMMARY OF FILTERCHECK STATISTICAL CALCULATION FOR CH124 MGB LUBE#1

	FE Bin 1 (#/h)	FE Bin 2 (#/h)	FE Bin 3 (#/h)	FE Bin 4 (#/h)	NFE Bin 1 (#/h)	NFE Bin 2 (#/h)	NFE Bin 3 (#/h)	NFE Bin 4 (#/h)	FE Mass (mg/h)	FE Counts (#/h)	NFE Counts (#/h)
Average	2.02	0.04	0.00	0	0	0	0.00	0	0.08	2.06	0.00
Standard Deviation	1.52	0.04	0.00	0	0	0	0.00	0	0.06	1.56	0.00
Number of data points	10	10	10	10	10	10	10	10	10	10	10
COV Limit (%)	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27
COV (%)	0.76	1.05	1.62	0	0	0	0.00	0	0.77	0.76	0.00
+2 Sigma	5.06	0.13	0.00	0	0	0	0.00	0	0.20	5.18	0.00
+4 Sigma	8.10	0.22	0.01	0	0	0	0.00	0	0.32	8.29	0.00

TABLE E-3 - BREAK-DOWN WEAR (TSO > 1389 HRS.): SUMMARY OF FILTERCHECK STATISTICAL CALCULATION FOR CH124 MGB LUBE#1

	FE Bin 1 (#/h)	FE Bin 2 (#/h)	FE Bin 3 (#/h)	FE Bin 4 (#/h)	NFE Bin 1 (#/h)	NFE Bin 2 (#/h)	NFE Bin 3 (#/h)	NFE Bin 4 (#/h)	FE Mass (mg/h)	FE Counts (#/h)	NFE Counts (#/h)
Average	0.00	0.00	0.00	0	0.31	0	7.90	0	0.00	0.00	0.00
Standard Deviation	0.00	0.00	0.00	0	0.16	0	4.11	0	0.00	0.00	0.00
Number of data points	3	3	3	3	3	0	3	0	3	0	0
COV Limit (%)	0.15	0.15	0.15	0.15	0.15	0.00	0.15	0.00	0.15	0.00	0.00
COV (%)	0.00	0.00	0.00	0	0.50	0	0.52	0	0.00	0.00	0.00
+2 Sigma	0.00	0.00	0.00	0	0.63	0	16.13	0	0.00	0.00	0.00
+4 Sigma	0.00	0.00	0.00	0	0.94	0	24.35	0	0.00	0.00	0.00

TABLE E-4 - BREAK-IN WEAR (TSO < 280 HRS.): SUMMARY OF FILTERCHECK STATISTICAL CALCULATION FOR CH124 MGB LUBE#2

	FE Bin 1 (#/h)	FE Bin 2 (#/h)	FE Bin 3 (#/h)	FE Bin 4 (#/h)	NFE Bin 1 (#/h)	NFE Bin 2 (#/h)	NFE Bin 3 (#/h)	NFE Bin 4 (#/h)	FE Mass (mg/h)	FE Counts (#/h)	NFE Counts (#/h)
Average	2.50	0.06	0.01	0.00	0.00	0.00	0.00	0.00	0.11	2.56	0.00
Standard Deviation	3.68	0.11	0.01	0.00	0.01	0.00	0.00	0.00	0.17	3.81	0.01
Number of data points	5	5	5	5	5	5	5	5	5	5	5
COV Limit (%)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
COV (%)	1.47	1.92	2.24	0.00	2.24	0.00	0.00	0.00	1.60	1.49	2.24
+2 Sigma	9.86	0.28	0.04	0.00	0.02	0.00	0.00	0.00	0.45	10.18	0.02
+4 Sigma	17.22	0.51	0.07	0.00	0.03	0.00	0.00	0.00	0.79	17.79	0.03

TABLE E-5 - NORMAL WEAR (280 HRS. < TSO < 1389 HRS.): SUMMARY OF FILTERCHECK STATISTICAL CALCULATION FOR CH124 MGB LUBE#2

	FE Bin 1 (#/h)	FE Bin 2 (#/h)	FE Bin 3 (#/h)	FE Bin 4 (#/h)	NFE Bin 1 (#/h)	NFE Bin 2 (#/h)	NFE Bin 3 (#/h)	NFE Bin 4 (#/h)	FE Mass (mg/h)	FE Counts (#/h)	NFE Counts (#/h)
Average	1.14	0.02	0.00	0.00	0.01	0.00	0.00	0.00	0.05	1.17	0.01
Standard Deviation	0.65	0.01	0.00	0.00	0.04	0.00	0.00	0.00	0.02	0.65	0.04
Number of data points	9	9	9	9	9	9	9	9	9	9	9
COV Limit (%)	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26
COV (%)	0.57	0.69	1.73	0.00	3.00	3.00	0.00	0.00	0.53	0.56	3.00
+2 Sigma	2.44	0.05	0.01	0.00	0.10	0.01	0.00	0.00	0.09	2.47	0.10
+4 Sigma	3.73	0.08	0.01	0.00	0.18	0.01	0.00	0.00	0.14	3.78	0.19

TABLE E-6 - WEAR-OUT WEAR (TSO > 1389 HRS.): SUMMARY OF FILTERCHECK STATISTICAL CALCULATION FOR CH124 MGB LUBE#2

	FE Bin 1 (#/h)	FE Bin 2 (#/h)	FE Bin 3 (#/h)	FE Bin 4 (#/h)	NFE Bin 1 (#/h)	NFE Bin 2 (#/h)	NFE Bin 3 (#/h)	NFE Bin 4 (#/h)	FE Mass (mg/h)	FE Counts (#/h)	NFE Counts (#/h)
Average	0.14	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.15	0.00
Standard Deviation	0.07	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00
Number of data points	2	2	2	2	2	2	2	2	2	2	2
COV Limit (%)	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
COV (%)	0.52	1.41	0.00	0.00	0.00	0.00	0.00	0.00	0.24	0.36	0.00
+2 Sigma	0.29	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.27	0.00
+4 Sigma	0.43	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.38	0.00

TABLE E-7 - BREAK-IN WEAR (TSO < 280 HRS.): SUMMARY OF FILTERCHECK STATISTICAL CALCULATION FOR CH124 MGB Q PUMP

	FE Bin 1 (#/h)	FE Bin 2 (#/h)	FE Bin 3 (#/h)	FE Bin 4 (#/h)	NFE Bin 1 (#/h)	NFE Bin 2 (#/h)	NFE Bin 3 (#/h)	NFE Bin 4 (#/h)	FE Mass (mg/h)	FE Counts (#/h)	NFE Counts (#/h)
Average	0.28	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.29	0.00
Standard Deviation	0.42	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.02	0.44	0.00
Number of data points	6	6	6	6	6	6	6	6	6	6	6
COV Limit (%)	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21
COV (%)	1.54	1.10	2.45	0.00	0.00	0.00	0.00	0.00	1.56	1.52	0.00
+2 Sigma	1.12	0.04	0.02	0.00	0.00	0.00	0.00	0.00	0.07	1.17	0.00
+4 Sigma	1.97	0.06	0.03	0.00	0.00	0.00	0.00	0.00	0.11	2.04	0.00

TABLE E-8 - NORMAL WEAR (280 HRS. < TSO < 1389 HRS.): SUMMARY OF FILTERCHECK STATISTICAL CALCULATION FOR CH124 MGB Q PUMP

	FE Bin 1 (#/h)	FE Bin 2 (#/h)	FE Bin 3 (#/h)	FE Bin 4 (#/h)	NFE Bin 1 (#/h)	NFE Bin 2 (#/h)	NFE Bin 3 (#/h)	NFE Bin 4 (#/h)	FE Mass (mg/h)	FE Counts (#/h)	NFE Counts (#/h)
Average	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.17	0.00
Standard Deviation	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.18	0.00
Number of data points	11	11	11	11	11	11	11	11	11	11	11
COV Limit (%)	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
COV (%)	1.03	1.05	2.22	N/A	3.32	N/A	N/A	N/A	1.04	1.02	3.31
+2 Sigma	0.52	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.57	0.00
+4 Sigma	0.86	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.04	0.88	0.00

TABLE E-9 - WEAR-OUT WEAR (TSO > 1389 HRS.): SUMMARY OF FILTERCHECK STATISTICAL CALCULATION FOR CH124 MGB Q PUMP

	FE Bin 1 (#/h)	FE Bin 2 (#/h)	FE Bin 3 (#/h)	FE Bin 4 (#/h)	NFE Bin 1 (#/h)	NFE Bin 2 (#/h)	NFE Bin 3 (#/h)	NFE Bin 4 (#/h)	FE Mass (mg/h)	FE Counts (#/h)	NFE Counts (#/h)
Average	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.21	0.00
Standard Deviation	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.21	0.00
Number of data points	2	2	2	2	2	2	2	2	2	2	2
COV Limit (%)	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
COV (%)	0.97	1.41	N/A	N/A	N/A	N/A	N/A	N/A	0.98	0.98	N/A
+2 Sigma	0.61	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.62	0.00
+4 Sigma	1.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.04	1.03	0.00

TABLE E-10 - SUMMARY OF FILTERCHECK STATISTICAL CALCULATION FOR CH124 T58 TURBINE ENGINE LUBE FILTER

	FE Bin 1 (#/h)	FE Bin 2 (#/h)	FE Bin 3 (#/h)	FE Bin 4 (#/h)	NFE Bin 1 (#/h)	NFE Bin 2 (#/h)	NFE Bin 3 (#/h)	NFE Bin 4 (#/h)	FE Mass (mg/h)	FE Counts (#/h)	NFE Counts (#/h)
Average	1.03	0.08	0.00	0	0.000721	0	0.00	0	0.06	1.12	0.00
Standard Deviation	1.08	0.17	0.01	0	0.002418	0	0.00	0	0.08	1.24	0.00
Number of data points	22	22	22	22	22	22	22	22	22	22	22
COV Limit (%)	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
COV (%)	1.04	2.17	1.78	0	3.356418	0	0.00	0	1.34	1.11	3.36
+2 Sigma	3.19	0.43	0.02	0	0.005557	0	0.00	0	0.23	3.59	0.01
+4 Sigma	5.34	0.78	0.03	0	0.010394	0	0.00	0	0.39	6.07	0.01

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For the past two decades filter debris analysis (FDA) has been used as a diagnostic technique to ascertain information about the wear state of CH124 main gearboxes (MGB) and turbine engines.

Two FDA technologies, which optimize sample preparation and eliminate analyst variability were evaluated for first-line filter debris analysis capability for the CH124 Sea King helicopter.

1. FilterCHECK, which backwashes the filter, running the fluid through a sensor which simultaneously counts and sizes metallic wear particles.
2. Intelligent Debris Analyzer (IDA), which optically counts, sizes, and determines the morphology of metallic wear particles.

The Intelligent Debris Analyzer (IDA) was an accurate FDA analysis tool but was found to be sensitive to the operator and its environment. Therefore, the IDA is an unlikely candidate for first-line FDA

The FilterCHECK was observed to be an accurate filter debris extraction and analysis tool for use by first-line maintenance technicians. Therefore, FilterCHECK should be field trialed to further assess its design, operation and operator training requirements.

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Filter Debris Analysis (FDA)
FilterCHECK
Intelligent Debris Analyser (IDA)
Condition Monitoring
First-Line
Helicopter
Transmission
Main Gearbox
Turbine